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ANALYSIS OF BART'S ENERGY CONSUMPTION FOR INTERIM SYSTEM OPERATIONS

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The BART Impact Program is a comprehensive, policy-oriented study and evaluation of the impacts of the San Francisco Bay Area's new rapid transit system (BART).

The program is being conducted by the Metropolitan Transportation Commission, a nine-county regional agency established by state law in 1970.

The program is financed by the U. S. Department of Transportation, the U. S. Department of Housing and Urban Development, the National Science Foundation, and the California Department of Transportation. Management of the Federally-funded portion of the program is vested in the U. S. Department of Transportation.

The BART Impact Program covers the entire range of potential rapid transit impacts, including impacts on traffic flow, travel behavior, land use and urban development, the environment, the regional economy, social institutions and life styles, and public policy. The incidence of these impacts on population groups, local areas, and economic sectors will be measured and analyzed. The benefits of BART, and their distribution, will be weighed against the negative impacts and costs of the system in an objective evaluation of the contribution that the rapid transit investment makes toward meeting the needs and objectives of this metropolitan area and all of its people.

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ANALYSIS OF BART'S ENERGY CONSUMPTION FOR INTERIM SYSTEM OPERATIONS

JUNE 1975

WORKING PAPER

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U.S. DEPARTMENT OF TRANSPORTATION

OFFICE OF TRANSPORTATION PLANNING ASSISTANCE AND
URBAN MASS TRANSPORTATION ADMINISTRATION
400 SEVENTH STREET, S.W.
WASHINGTON, D.C. 20590

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16. Abstract

The Bay Area Rapid Transit (BART) System is the first areawide rail rapid transit system to be built in the United States in 50 years. This system includes 71 miles of track, 34 stations, and such technological advancements as a regenerative braking system plus light, all aluminum cars designed for high acceleration and maximum spee of 80 miles per hour. This study investigates the historical energy consumption of the BART System, estimates BART's energy consumption for ultimate design service levels (approximately twice the present level), and compares BART's energy consumption to that of other rail rapid transit systems and alternate modes.

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Bay Area Rapid Transit (BART) System, BART Impact Program, energy consumption, rail rapid transit, urban transportation

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TRANSPORTATION SYSTEM AND TRAVEL BEHAVIOR PROJECT

BART IMPACT PROGRAM

DOCUMENT NUMBER WP 14-3-75
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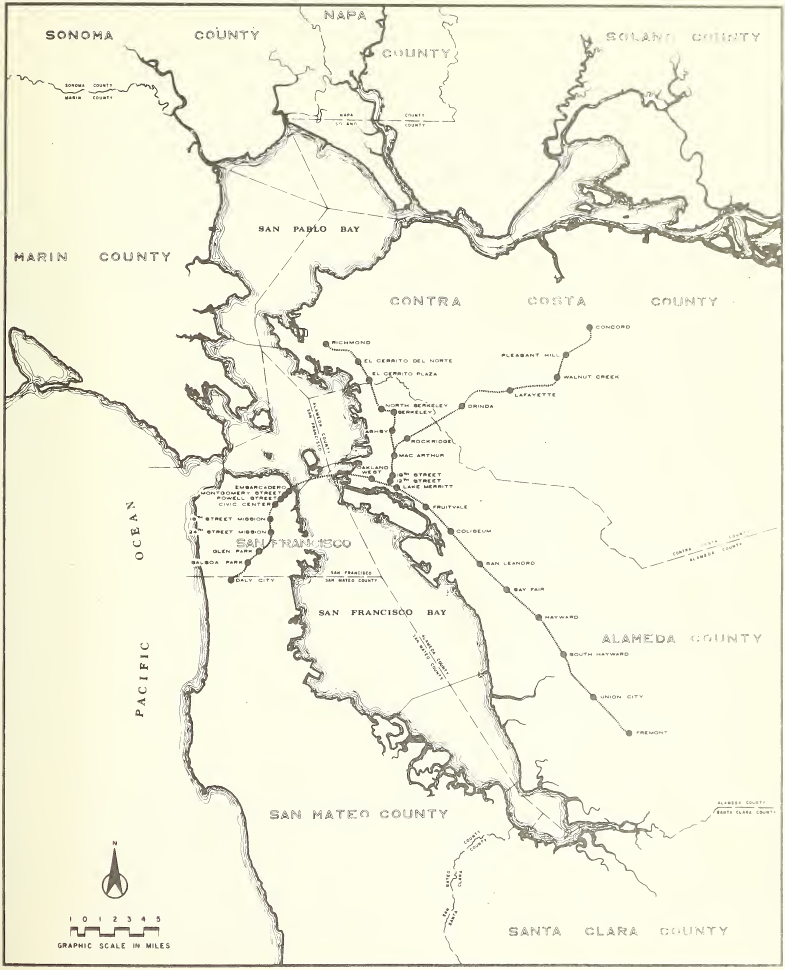

BAY AREA RAPID TRANSIT SYSTEM

PEAT, MARWICK, MITCHELL & CO.
SAN FRANCISCO

PREFACE

This working paper was produced as part of the Transportation System and Travel Behavior (TSTB) Project of the BART Impact Program. The focus of the energy analysis was presented in the TSTB Research Plan* and the design further detailed in the BART Energy Analysis working note.**

In the course of preparing this working paper, cooperation and assistance was provided by the BART staff; most notably Ms. Miriam Hawley and Mr. Robert Miller. Their contributions are gratefully acknowledged; however, responsibility for the contents of this report rests entirely with the authors.

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*Transportation System and Travel Behavior Project Research Plan, BART Impact Program Document No. PD 14-3-75, prepared by Peat, Marwick, Mitchell & Co., Burlingame, California, for the Metropolitan Transportation Commission, Berkeley, California, May 1975.

**"Working Note--BART Energy Analysis," BART Impact Program Document No. WN 8-3-75, prepared by Peat, Marwick, Mitchell & Co., Burlingame, California, for the Metropolitan Transportation Commission, Berkeley, California, April 1975.

SUMMARY

BART's energy consumption has undergone the following changes since the inception of service in September 1972:

- Total consumption has risen from 5.8 x 10^6 kilowatt hours (kwh) per month to a peak of over 17 x 10^6 kwh per month.
- Energy consumption per production unit has decreased from a peak of 1.7 kwh per passenger mile (kwh/pm) to a low of 0.39 kwh/pm.
- Traction energy has increased from 25% to 70% of total system energy.

A forecast of BART's energy consumption for full system service (e.g., 34 stations, 600 cars, 4.3 million car-miles per month, and 80 million passenger-miles per month) suggests the following energy consumption characteristics for full-system operation:

- A total monthly energy consumption of 27.5 million kwh.
- An energy consumption per production unit of 0.34 kwh/pm.
- Traction energy will be 80% of all energy consumed, while station and maintenance energies will be 17% and 3%, respectively.

BART's energy consumption is comparable to that of other heavy rail transit systems and projections indicate that when full operating levels are achieved, BART will be more efficient than the average within the United States for these systems. This is due mainly to BART's lighter vehicles.

BART vehicles consume less energy, on a per seat-mile basis, than all other modes except buses. Compared with BART's projected traction energy consumption, buses consume between 65% and 85% as much energy per seat-mile. However, it must be realized that BART vehicles travel significantly faster than buses. In addition, BART cars can realize a load factor of about 300% during peak conditions, while buses can only accept 150% to 175% of their seating capacity. Thus, at peak loads, the energy consumed per passenger-mile is essentially equal for the two modes.

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ENERGY CONSUMPTION ANALYSIS

Introduction

This Working Paper:

- Describes BART's historical operating energy consumption including:
  - Maintenance energy
  - Station energy
  - Traction energy
- Provides parametric estimates of BART's operating energy consumption based on:
  - Car-miles
  - Passenger-miles
  - Number of cars in the system
- Estimates BART's energy consumption for full-system operations
- Compares BART's energy consumption to that of other rail rapid transit systems and alternative modes

BART's Historical Operating Energy Consumption

BART's energy consumption, as illustrated in Figure 1, is segregated into three main categories:

1. Maintenance energy, which includes all energy consumed in the Concord, Richmond, Oakland, and Alameda shops and yards (except traction energy from the third rail).
2. Station energy, which includes all energy consumed by BART stations and parking lots (e.g., lighting), for the ventilation of the Transbay Tube and Berkeley Hills Tunnel, and for the operation of the BART administration building at the Lake Merritt Station.
3. Traction energy, which is used to propel the cars and to power their auxiliary functions (air conditioners, heaters, lights, etc.), as provided by the 1,000-volt DC third rail.

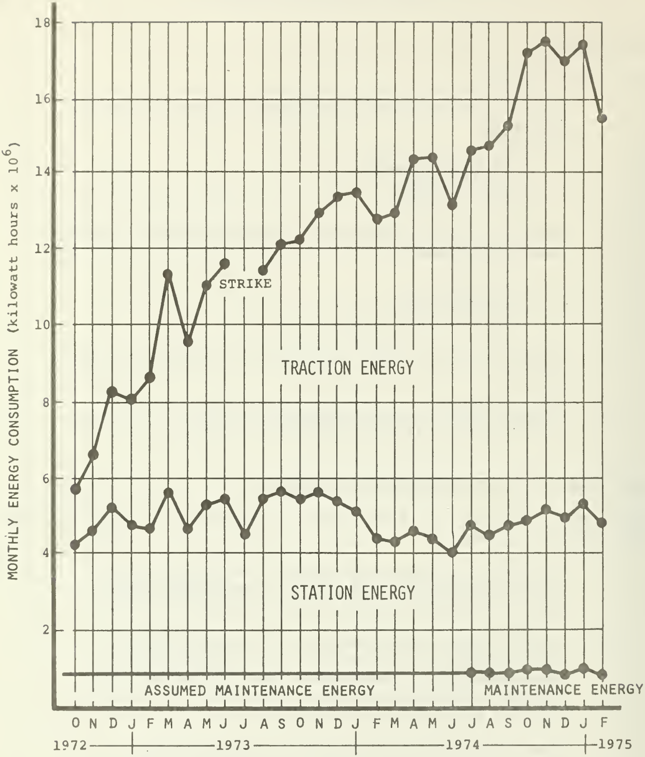

FIGURE 1

HISTORICAL BART MONTHLY ENERGY CONSUMPTION

Maintenance Energy. Only eight months (July 1974 to February 1975) of maintenance energy data are conveniently available from BART files. Acquisition of maintenance energy data for time periods prior to July 1974 would require more time than was available for the present analysis. However, the data that were obtained indicate a very constant rate of energy consumption for maintenance purposes. For the time periods observed, the monthly energy consumption ranged from a high of 0.95×10^6 kilowatt hours (kwh) to a low of 0.82×10^6 kwh with an average of 0.88×10^6 kwh. Considering the relatively small magnitude and the stability of maintenance energy consumption, it is not inappropriate to assume a consumption level of 0.88×10^6 kwh per month prior to July 1974, as indicated in Figure 1.

Station Energy. Subtracting the observed and assumed monthly maintenance energy consumptions from the total of maintenance and station energy consumption (i.e., all nontraction energy consumption) results in the station energy consumption presented in Figures 1 and 2. Prior to August 1973, station energy consumption levels showed wide variations, because of the rapidly increasing levels of BART service and varying degrees of construction activity at stations not yet open. From August through November 1973--when all stations were either in operation, physically complete, or very nearly complete--the monthly energy consumption was approximately 4.6×10^6 kwh. Prompted by the Arab oil embargo, BART implemented energy conservation measures in its station operations beginning December 1973. Despite the fact that the opening of the San Francisco Line introduced eight stations into operation in mid-November 1973, monthly station energy consumption dropped to approximately 3.4×10^6 kwh by February 1974. From this low point, energy consumption began to rise slowly to its present level of about 4.0×10^6 kwh per month; this is probably due to seasonal variations and possibly some slackening of conservation measures.

Traction Energy. Traction energy is consumed by the BART cars for propulsion and for powering their auxiliary functions such as air conditioning, heating, lights, etc. Propulsion energy is used to propel the cars and the payload (i.e., the passengers). Propulsion energy is consumed during operating hours for revenue service and during nonrevenue hours for testing. Auxiliary energy is consumed at all times by most cars, since all cars (except those in the shop for major repairs) are kept "hot" (i.e., the climate control equipment is functioning).

Traction energy consumption has increased steadily since the inception of BART service as the number of car-miles and the number of cars in operation have increased. The reductions in traction energy consumption in June 1974 and February 1975 are associated with corresponding reductions in the number of car-miles of service.

Parameterization of System Energy Consumption

Total system energy consumption is presented in Figure 3 on a per car-mile basis and in Figure 4 on a per passenger-mile basis. These figures suggest the following:

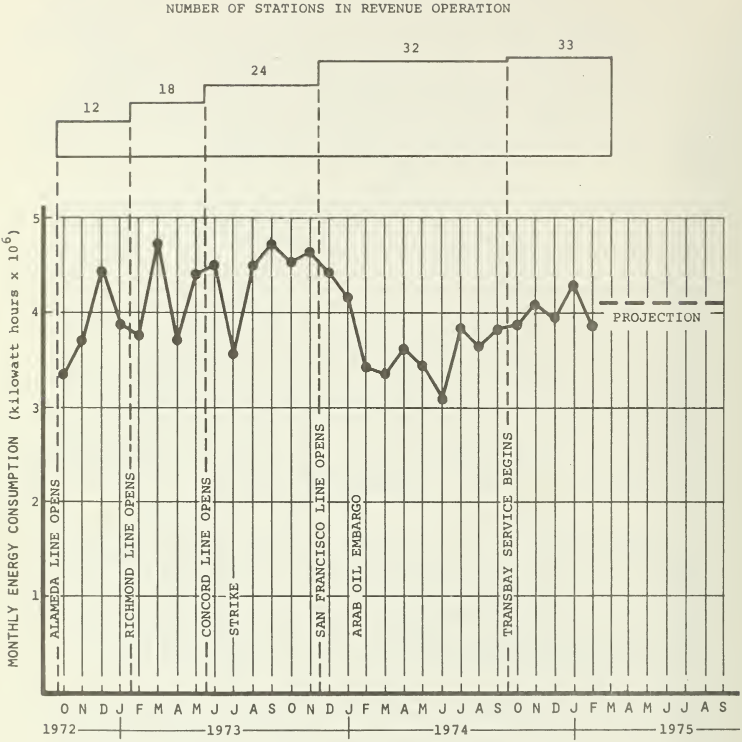

FIGURE 2

HISTORICAL BART MONTHLY STATION ENERGY CONSUMPTION

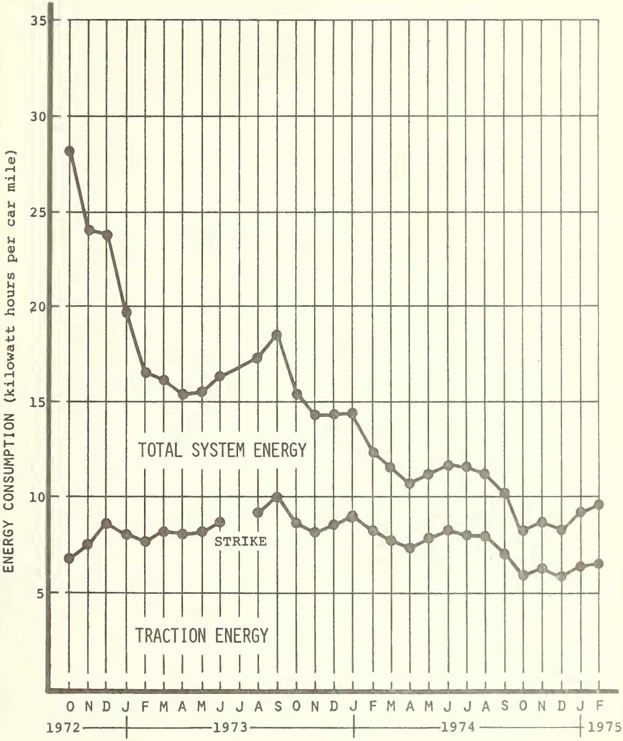

FIGURE 3

BART ENERGY CONSUMPTION PER CAR MILE

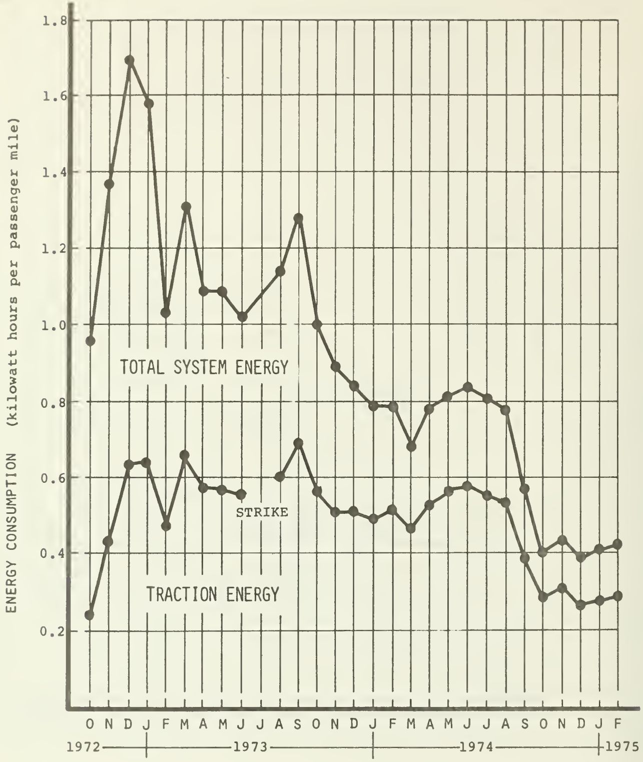

FIGURE 4

BART ENERGY CONSUMPTION PER PASSENGER MILE

- As BART service and patronage have increased, the energy consumption per car-mile and per passenger-mile have decreased to 25% to 30% of original energy consumption. Essentially, the fixed station and maintenance energy consumption is being allocated among a greater volume of production units (car-miles or passenger-miles).

- As BART service and patronage have increased, traction energy has assumed a greater percentage of total energy consumption. During early operations, traction energy comprised approximately 25% of the total energy consumption, whereas presently, it comprises 70%.

- In the period following initiation of transbay BART service, traction energy consumption per car-mile decreased. This was due to the fact that although the number of car-miles (on which the propulsion energy component of traction energy is directly contingent) increased 63% between August and October 1974, the number of cars (on which the auxiliary energy component of traction energy is based) only increased 9%. Traction energy consumption, therefore, increased at a rate between the increases of its two components--21% from August to October--and the traction energy consumed per car-mile decreased.

  Also, in the same period, energy consumption per passenger-mile decreased significantly because of the decrease in energy consumption per car-mile and the increased number of passengers per car.

Forecasts of BART's Energy Consumption

Maintenance Energy. Considering the relative stability of historical maintenance energy consumption with increasing system operations, it appears reasonable to assume that maintenance energy consumption will remain relatively constant in the future. With increased fleet size, the level of activity (and thus energy consumption) may increase slightly. For this analysis, an ultimate monthly maintenance energy consumption of 1.0×10^6 kwh will be used. (Note: The working note describing the TSTB Phase I energy analysis suggested a linear regression analysis with monthly maintenance energy consumption as the dependent variable and the number of days in the month and the number of cars in the system as the independent variables. Such an analysis was performed but the results were inconclusive and are therefore not presented.)

Station Energy. A trend curve was fitted by hand to the post-oil embargo energy consumption data points shown in Figure 2. Assuming that the current revenue hours of BART operation continue, and that the present policies pertaining to station operating procedures during revenue and nonrevenue periods continue (e.g., turning most station lights off during nonrevenue periods), a steady state of station energy consumption for the 34-station system of approximately 4.1 x 10^6 kwh per month can be estimated; this is an average monthly consumption of 0.12 x 10^6 kwh per station.

The estimated station energy consumption of 4.1 x 10^6 kwh per month assumes the present service level of 70 operational hours per week.

Healy (Ref. 5)* determined that hourly station energy consumption in nonrevenue periods was 92% as great as energy consumption during revenue periods for June of 1973. During the Arab oil embargo, station energy conservation measures were taken that decreased total station energy consumption from a peak of approximately 4.6 x 10^6 kwh per month to the present stable level of 4.1 x 10^6 kwh per month (Fig. 2) or a decrease of 11%. Assuming that the majority of energy conservation measures were made during nonrevenue periods, implies that station energy consumption during these periods decreases to 82% of the pre-embargo level. Thus, the hourly energy consumption during nonrevenue periods is assumed as 75% as great as the present hourly consumption during revenue periods and will continue so into the future.

Utilizing this ratio of 0.75:1, the following procedure may be used to estimate monthly station energy consumption for the projected ultimate service level of 140 hours per week (20 hours per day, 7 days per week).

$$E_{70} = (70) \times (K) + (98) \times (0.75K) = 4.1 \times 10^6 \text{ kwh}$$

This results in a value for K of 28.57 x 10^3 kwh which is then utilized in the following equation:

$$E_{140} = (140) \times (K) + (28) \times (0.75K) = 4.6 \times 10^6 \text{ kwh}$$

where

E_{70} = monthly station energy consumption at the present service level of 70 hours per week

E_{140} = monthly station energy consumption at the ultimate service level of 140 hours per week

K = A constant relating revenue-hour station energy consumption to monthly station energy consumption

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*Reference numbers in this working paper correspond to the numbers of publications cited in the Bibliography at the end.

Therefore, the estimated monthly station energy consumption for the ultimate service level of 140 hours per week is approximately 4.6×10^6 kwh or $.14 \times 10^6$ kwh per station. (Note: The working note describing the TSTB Phase I energy analysis suggested a linear regression of the monthly station energy consumption versus the number of days in the month. Such an analysis was performed utilizing both the calendar days in each month and the operating days; however, the results were inconclusive and are therefore not presented.)

Combining station and maintenance energy estimates results in a projected energy consumption of 5.6×10^6 kwh per month. This compares to a monthly station and maintenance energy consumption of 7.1×10^6 kwh projected by Healy (Ref. 5) based on June 1973 observations. The difference between these estimates can largely be attributed to the fact that Healy based his estimate on empirical data obtained prior to the energy conservation measures initiated in the winter of 1973-74.

Traction Energy. A full analysis of traction energy consumption requires that revenue and nonrevenue periods be analyzed separately. Table 1 illustrates the five major elements of traction energy consumption and the key variables affecting these elements. Unfortunately, no record of test car-miles is kept, and there is no convenient way to measure hot car hours, either during revenue or nonrevenue periods. If test car propulsion energy consumption is assumed neglibible relative to other traction energy consumption and the total number of hot car hours is proportional to the number of cars in the system, then the total traction energy consumption can be considered a function of three independent variables: (1) car-miles, (2) passenger-miles, and (3) number of cars in the system.

Utilizing monthly data from the inception of BART service to the present (see Figure 5), several multiple linear regression analyses were performed defining traction energy as the dependent variable and various combinations of car-miles, passenger-miles, and cars in the system as the independent variables. The model incorporating monthly traction energy as the dependent variable and car-miles and cars in the system as the independent variables was the most viable for predictive purposes. Passenger-miles can be omitted as an independent variable due to the very high correlation between passenger-miles and car-miles, as exhibited in Figure 5. The estimated model of traction energy consumption is as follows:

$$E_t = 1740 + \underset{(3.15)}{17.8\,(C)} + \underset{(.00058)}{.0022\,(D_c)}$$

where:

E_t = monthly traction energy consumed (10^3 kwh)

C = number of cars in the system

D_c = car-miles per month

Table 1

TRACTION ENERGY

Dependent Variable	Independent Variable
P_{v1} = Revenue Vehicle Propulsion	D_{v1} = Revenue Car-Miles
P_p = Revenue Payload Propulsion	D_p = Revenue Passenger-Miles
A_1 = Revenue Auxiliary Energy	T_1 = Revenue Hot Car Hours
P_{v2} = Nonrevenue Vehicle Propulsion	D_{v2} = Test Car-Miles
A_2 = Nonrevenue Auxiliary Energy	T_2 = Nonrevenue Hot Car Hours

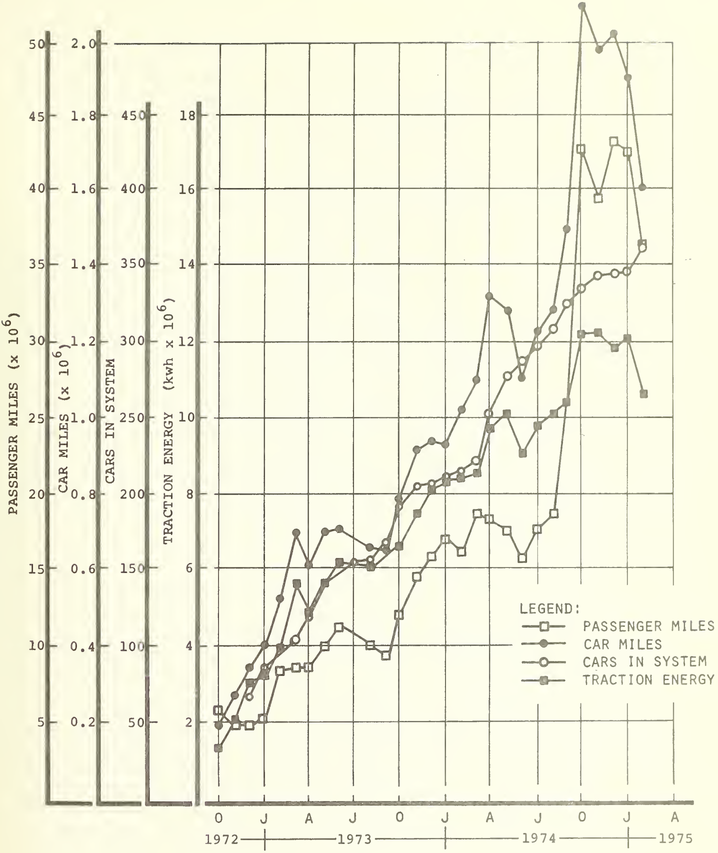

FIGURE 5

HISTORICAL BART MONTHLY TRACTION ENERGY CONSUMPTION

This estimation is of high quality; all of the coefficients have the "correct" sign, the model is significant beyond the 0.001 level of confidence using an F test for the significance of the regression as a whole, and the multiple correlation coefficient (r^2) is 0.98.

Utilizing this equation and assuming a full-system operation of 600 cars and 4,300,000 car-miles per month produces an ultimate system traction energy consumption of 21.9 x 10^6 kwh per month. This is equivalent to 5.1 kwh per car-mile (kwh/cm) which correlates strongly with Healy's (Refs. 4 and 5) projection of 5.0 kwh/cm.

All BART vehicles are equipped with regenerative braking equipment designed to return power to the system during braking. During the 2-1/2-year period of BART operation for which traction energy consumption data is presented in Figure 5, the regenerative braking system was largely ineffectual in reducing BART's energy consumption because of the relatively large spacing between trains. Further, since February 1975, the power supply system has been separated into distinct "blocks" thereby prohibiting the flow of power from a decelerating to an accelerating train. As train spacings are reduced and if the blocking of the power system is eliminated, the regenerative braking system will act as a power source and reduce the net external power requirements. Under these circumstances, Healy (Ref. 5) has estimated that regenerative braking could supply as much as 0.8 kwh/cm during peak operating periods (i.e., minimum headways) and BART has estimated that the average reduction in traction energy consumption for all operating periods (i.e., peak and off-peak) would be 0.25 kwh/cm. This would result in a 5% reduction in traction energy and a 4% reduction in total system energy consumption.

Forecast of Energy Consumption for Full-System Operation. BART's monthly energy consumption in the period following transbay BART service (October 1974 to February 1975) is compared in Table 2 to corresponding estimates for full BART service. For the purposes of this analysis, full service has been assumed as 4,300,000 car-miles per month and 80,000,000 passenger-miles per month, or about twice the current levels. The projections for each of the three principal components of energy consumption are based on the assumptions and procedures described above.

This simple analysis suggests two major points. First, while total monthly energy consumption will increase about 64% from current operations to the assumed full-system operations, the corresponding energy consumption per car-mile will decrease by about 25%, and the corresponding energy consumption per passenger-mile will decrease by about 19%. Second, the proportion of total energy consumption devoted to traction energy will increase from about 70% under current operations to about 80% under the assumed full-system operation.

Table 2

FORECAST OF BART ENERGY CONSUMPTION FOR FULL-SYSTEM OPERATIONS

	BART Energy Consumption		
Post Transbay BART (October 1974-February 1975)[a]	Total Per Month (kwh x 10^6)	Per Car-Mile (kwh)	Per Passenger-Mile (kwh)
Traction Energy	11.9	6.0	0.30
Station Energy	4.0	2.0	0.10
Maintenance Energy	0.9	0.5	0.02
Total	16.8	8.5	0.42
Projected Ultimate System[b]			
Traction Energy[c]	21.9	5.1	0.27
Station Energy	4.6	1.1	0.06
Maintenance Energy	1.0	0.2	0.01
Total[d]	27.5	6.4	0.34

---

a. Based on 350 cars, 2,000,000 car-miles per month, and 40,000,000 passenger-miles per month.

b. Assumes 600 cars, 4,300,000 car-miles per month, and 80,000,000 passenger-miles per month.

c. This does not include consideration of the potential contribution of the regenerative braking system which BART has estimated could reduce traction energy consumption by an average of 5%.

d. This forecast may be contrasted with BART's forecast of total monthly energy consumption of 29.4 x 10^6 kwh for projected ultimate system operation including regenerative braking.

Comparison of BART's Energy Consumption To That of Other Rail Rapid Transit Systems and Other Modes

Table 3 presents the energy consumptions, capacities, and energy consumptions per production unit for modes currently available in the Bay Area. The data for all of the modes except BART have been derived from various secondary sources.

Comparison of BART to Other Rail Rapid Transit Services. A comparison of BART's energy consumption to that of other rail rapid transit services might be based on the energy consumed per seat-mile. However, while BART is designed to seat the majority of passengers, other systems such as the subway systems in New York City, Chicago, and Philadelphia have been designed to provide more limited seating but greater room for standing in order to serve a larger number of people per car. Comparison of the systems on the basis of energy per seat-mile would, therefore, present an erroneous view of the actual situation. Ideally, a production unit more clearly reflecting a vehicle's passenger carrying capabilities irrespective of seating configuration should be utilized. Such a unit which could be utilized in the future is energy consumed per unit floor area per vehicle mile. However, for this analysis, energy consumed per car-mile is used.

It is emphasized that energy consumption data for other systems are available for traction energy only, and do not include maintenance or station energy. Hence, this comparison focuses on BART's traction energy consumption. Presently, BART's traction energy consumption is approximately 10% above the national average probably because of BART's short operating hours, the relatively high percentage of cars which are out of revenue service, and the fact that auxiliary power is consumed by BART vehicles 100% of the time, while revenue service is only available 42% of the time. As BART's operations expand from 24 million to 50 million annual car-miles and from 70 to 140 weekly operating hours, its traction energy consumption (on a per car-mile basis) will decline to 5.1 kwh/cm or 10% below the national average. The main reasons for BART's projected traction power consumption being lower than the national average is that BART cars weigh about 28,000 pounds or 33% less than New York City subway cars. The improvement in BART's traction energy efficiency relative to the other rail rapid transit systems because of the lighter weight of its cars is partially offset, however, by increased drag due to the high operating speeds (80 mph) of BART cars, in addition to high rates of acceleration.

Comparison of BART to Other Modes. Inasmuch as the units for describing the energy consumption of electrically powered vehicles are different from those used to describe the energy consumption of vehicles powered by internal combustion engines, both estimates were converted to the common units of British thermal units (Btu) per production unit (e.g., seat-miles or passenger-miles). This conversion assumed an efficiency factor of 30% for the generation and transmission of electrical power. It should be recognized, however, that other sources besides petroleum can be utilized to generate electricity.

Table 3

MODAL ENERGY CONSUMPTION

Mode	Energy Consumption	Weight (lbs)	Seats	Weight per Seat (lbs)	Btu/sm[a]	Btu/pm[b] Load Factor 25%	Btu/pm[b] Load Factor 50%	Btu/pm[b] Load Factor 100%
Auto (average urban)[c]	11.5 mpg	4,000	6	670	1,810	7,240	3,620	1,810
Auto (subcompact)[c]	25 mpg	2,000	4	500	1,250	5,000	2,500	1,250
Jitney[c]	8 mpg	8,000	8	1,000	1,950	7,800	3,900	1,950
Demand Responsive Bus[c]	4.2 mpg	n.a.	19		1,570	6,280	3,140	1,570
Fixed Route Bus[c]	3.6 mpg	20,000	50	400	690	2,760	1,380	690
Express Bus[c]	4.8 mpg	20,000	50	400	520	2,080	1,040	520
Commuter Rail[c,d]	1,030 Btu/sm	Locomotive: 300,000 Cars: 180,000	500	1,800[e]	1,030	4,120	2,060	1,030
Trolley Coach[f]	3.62 kwh/cm		50		830	3,320	1,660	830
Street Car (LTV)[f]	4.49 kwh/cm		55		930	3,720	1,860	930
Heavy Rail Transit[f,g,h] (National Average)	5.50 kwh/cm	85,000			n.a.	n.a.	n.a.	n.a.
BART[i]								
Present System		57,000	72	790				
Traction	6.0 kwh/cm				950	3,390[j]	1,900	950
Station and Maintenance	2.5 kwh/cm				400	1,430	800	400
Total	8.5 kwh/cm				1,350	4,820	2,700	1,350
Ultimate System								
Traction[k]	5.1 kwh/cm				810	3,240	1,620	810
Station and Maintenance	1.3 kwh/cm				200	800	400	200
Total	6.4 kwh/cm				1,010	4,040	2,020	1,010

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n.a. = not available.

See continuing page for footnotes.

Table 3 (cont.)

NOTES

a. British thermal units per seat-mile. Assume 125,000 Btu per gallon of gasoline. This is as reported in References 4, 8, 9, and 10. For electrical energy, the direct conversion is 3,412 Btu/kwh.

b. British thermal units per passenger-mile.

c. Energy consumption, vehicle weight, and seating capacity reported in Reference 4.

d. Reference 4 reported the energy consumed by the Southern Pacific commuter service operating between San Francisco and San Jose. These trains consist mostly of double-deck cars with 150-seat capacities; however, there are several single-level cars with approximately half the capacity. The energy consumption and capacity as reported in this table are for an "average" train. The specific energy (Btu/sm) decreases significantly for peak hour trains that have up to 1,300 seats and increases for off-peak trains that may have only one car.

e. Weight calculated as follows:

Car weight = (180,000 lbs/car) ÷ (150 seats/car) = 1,200 lbs/seat
Locomotive weight = 300,000 lbs ÷ 500 seats = 600 lbs/seat
Train weight = 1,200 lbs/seat + 600 lbs/seat = 1,800 lbs/seat

f. Energy consumption from Reference 12. Seating capacity is assumed.

g. Since New York City represents the majority of heavy rail rapid transit usage in the United States (Table 6B.5, Ref. 6), the weight of a New York City transit car (Ref. 1) will be used for this category.

h. Energy consumed per seat-mile is not applicable for this mode as many rail transit cars, New York City's rail rapid transit in particular, are designed for standees as much as they are for seated passengers.

i. Energy consumption from BART records and PMM&Co. forecasts as presented in this working note.

j. These specific energy consumptions for the present system reflect the 28% load factor that was experienced by BART in February 1975.

k. This does not include the benefits of regenerative braking, which may decrease net traction energy requirements by as much as 0.8 kwh/cm (Ref. 5).

The following discussion focuses on the comparative energy consumption per seat-mile of the various modes. To the extent that the load factors of the various modes are significantly different, or could be differentially modified by private or public sector actions, it would also be desirable to assess the comparative energy consumption per passenger-mile. Presently, BART experiences a total system consumption of 1,350 Btu per seat-mile (Btu/sm) which includes 950 Btu/sm for traction energy and 400 Btu/sm for station and maintenance energy. Projections indicate that BART's energy consumption for full-system operations will decrease 25% from the present specific consumption to 1,010 Btu/sm; this includes 810 Btu/sm for traction energy.

As only traction energy consumption is readily available for all modes except BART, the comparison of BART and the other modes will be based solely on traction energy consumption. For the modes represented in Table 3, the energy consumed ranges from 520 Btu/sm for an express bus to 1,950 Btu/sm for an eight-passenger jitney; thus, the most energy efficient modes are the express and fixed route buses. This is contrary to the commonly held belief that a steel wheel on steel rail technology has the greatest energy efficiency. It must be realized, however, that traction energy consumption is a function of vehicle weight, acceleration, operating speed, and auxiliary energy consumption. While BART is a steel wheel on steel rail technology, several items must be noted when comparing it to the bus: (1) BART has almost twice the weight to seat ratio; (2) it employs a much higher rate of acceleration; (3) it travels up to 80 mph as opposed to 55 mph for an express bus and 30 to 35 mph for a regular fixed route bus; and (4) it has a climate control system that operates 24 hours a day. These elements cause BART to consume greater amounts of traction energy per seat-mile than bus despite the intrinsic energy effectiveness of its technology.

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